

CLAIMS

What is claimed is:

- 1 1. A method of selecting a data rate of a multicarrier communication
2 channel, the method comprising:
3 calculating signal to noise ratios (SNRs) for subcarriers of the multicarrier
4 communication channel from channel state information and a transmit power
5 level;
6 estimating a throughput for each of a plurality of data rates from the SNRs;
7 and
8 selecting one of the data rates based on the estimated throughputs.
- 1 2. The method of claim 1 wherein selecting one of the data rates comprises
2 selecting a combination of one of a plurality of modulations and one a plurality of
3 code rates associated with a highest of the estimated throughputs.
- 1 3. The method of claim 2 further comprising predicting packet error ratios
2 (PERs) from the SNRs for each of the data rates, and
3 wherein the estimating the throughput comprises estimating a throughput
4 for each of the data rates from the predicted PERs.
- 1 4. The method of claim 3 wherein predicting the PERs comprises using
2 SNR performance curves for the plurality of data rates to determine a PER for
3 each data rate, the SNR performance curves being predetermined and stored in a
4 memory of a receiving station.
- 1 5. The method of claim 3 wherein the predicting PERs comprises:
2 after demapping bits of a current packet, calculating a bit-error rate (BER),
3 based on a modulation of the current packet; and
4 after decoding the bits of the current packet, determining a PER for each of
5 the plurality of data rates based on a predetermined BER performance of a
6 decoder, the calculated BER, and a length of the current packet.

1 6. The method of claim 3 wherein the estimating the throughput comprises
2 estimating a throughput for each data rate of the plurality by multiplying an
3 associated one of the data rates by one minus the PER predicted for the associated
4 data rate.

1 7. The method of claim 2 further comprising generating transmit power
2 level and data rate instructions for a transmitting station, the transmit power level
3 and data rate instructions to include the selected modulation and code rate and a
4 selected transmit power level.

1 8. The method of claim 7 wherein the calculating operation is performed
2 by a receiving station based on a known transmit power level provided by the
3 transmitting station in a current packet, the current packet being a request to send
4 (RTS) packet,
5 wherein the method further comprises:
6 determining, by the receiving station, the channel state information from
7 channel estimates and noise power estimates performed on the RTS packet; and
8 sending, by the receiving station, the data rate instruction to the
9 transmitting station in a clear-to-send (CTS) packet, the transmitting station to
10 responsively transmit at least portions of a data packet to the receiving station in
11 accordance with the data rate instruction.

1 9. The method of claim 1 wherein the multicarrier communication channel
2 comprises either a standard-throughput channel or a high-throughput
3 communication channel, the standard-throughput channel comprising one
4 subchannel, the high-throughput channel comprising a combination of one or
5 more subchannels and one or more spatial channels associated with each
6 subchannel, and
7 wherein calculating the SNRs comprises calculating SNRs for each
8 subcarrier of the one or more subchannels and the one or more spatial channels
9 comprising the multicarrier communication channel from the transmit power level
10 and the channel state information, and

11 wherein the method further comprises generating a data rate instruction for
12 a transmitter, the data rate instruction to include a selected modulation and a
13 selected code rate for the one or more subchannels and the one or more spatial
14 channels comprising the multicarrier communication channel.

1 10. The method of claim 9 further comprising determining the channel
2 state information, the channel state information including noise power estimates
3 and a channel transfer function for each subcarrier of the one or more spatial
4 channels and the one or more subchannels.

1 11. The method of claim 9 wherein the high-throughput communication
2 channel comprises one of:
3 a wideband channel having up to four frequency separated subchannels;
4 a multiple-input-multiple-output (MIMO) channel comprising a single
5 subchannel having up to four spatial subchannels; and
6 a wideband-MIMO channel comprising two or more frequency separated
7 subchannels, each subchannel having two or more spatial channels.

1 12. The method of claim 11 wherein the wideband channel has a wideband
2 channel bandwidth of up to 80 MHz and comprises up to four of the subchannels,
3 wherein the subchannels are non-overlapping orthogonal frequency
4 division multiplexed channels,
5 wherein each subchannel has a subchannel bandwidth of approximately
6 20 MHz and comprises a plurality of orthogonal subcarriers, and
7 wherein the one or more spatial channels are non-orthogonal channels
8 associated with one of the subchannels.

1 13. The method of claim 9 wherein when the multicarrier communication
2 channel is a high-throughput communication channel, the one or more spatial
3 channels and the one or more subchannels are provided by a corresponding one or
4 more transmit antennas of a transmitting station.

1 14. The method of claim 9 wherein the subcarriers of an associated
2 subchannel have a null at substantially a center frequency of the other subcarriers
3 to achieve substantial orthogonality between the subcarriers of the associated
4 subchannel.

1 15. The method of claim 2 wherein the plurality of modulations comprise
2 binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 8PSK,
3 16-quadrature amplitude modulation (16-QAM), 32-QAM, 64-QAM, 128-QAM,
4 and 256-QAM, and
5 wherein the plurality of code rates comprise forward error correction
6 (FEC) code rates of $\frac{1}{2}$, $\frac{2}{3}$, and $\frac{3}{4}$.

1 16. The method of claim 1 wherein the data rate is further selected based
2 on a mean-variance adaptation that includes a mean channel power gain based on
3 channel gains for each of the subcarriers, a variance of the mean channel power
4 gain, and predicted SNRs for each of the data rates.

1 17. The method of claim 1 wherein estimating the throughput comprises
2 selecting various data rates for each of the subcarriers of the multicarrier
3 communication channel based on the SNR for the associated subcarrier, and
4 wherein estimating the throughput comprises calculating throughputs for
5 the multicarrier communication channel for the various data rates,
6 wherein selecting comprises selecting a single data rate for the subcarriers
7 of one or more spatial channels and one or more subchannels of the multicarrier
8 communication channel.

1 18. The method of claim 1 further comprising:
2 after calculating the SNRs for each subcarrier of the multicarrier
3 communication channel, calculating a subcarrier capacity for each of the data rates
4 based on the SNR calculated for an associated one of the subcarriers; and
5 refraining from estimating the throughput for each of the data rates, and
6 wherein selecting the data rate comprises selecting one of the data rates of
7 the plurality based on a sum of the subcarrier capacities.

1 19. The method of claim 18 wherein the subcarrier capacity for each
2 subcarrier is substantially calculated by multiplying a subcarrier frequency spacing
3 by a logarithm of one plus the SNR for the associated subcarrier divided by a
4 predetermined subcarrier SNR gap.

1 20. The method of claim 18 wherein selecting the data rate comprises:
2 determining an upper and a lower data rate based on the sum of the
3 subcarrier capabilities;
4 calculating a first number of subcarriers with capacities higher than the
5 upper data rate;
6 calculating a second number of subcarriers with capacities lower than the
7 lower data rate; and
8 selecting the upper data rate when a difference between the first and
9 second numbers is greater than a predetermined percentage of the subcarriers
10 comprising the multicarrier communication channel.

1 21. A communication station comprising:
2 channel state information processing circuitry to calculate signal to noise
3 ratios (SNRs) for subcarriers of the multicarrier communication channel from a
4 transmit power level and channel state information; and
5 data rate selection circuitry to estimate a throughput for each of a plurality
6 of data rates from the SNRs,
7 wherein the data rate selection circuitry selects one of the data rates based
8 on the estimated throughputs.

1 22. The communication station of claim 21 wherein the data rate selection
2 circuitry selects one of the data rates from a combination of one of a plurality of
3 modulations and one a plurality of code rates associated with a highest of the
4 estimated throughputs.

1 23. The communication station of claim 22 wherein the data rate selection
2 circuitry further predicts packet error ratios (PERs) from the SNRs for each of the
3 data rates and estimates the throughput comprises estimating a throughput for each
4 of the data rates from the predicted PERs.

1 24. The communication station of claim 23 wherein the data rate selection
2 circuitry predicts PERs comprises using SNR performance curves for the plurality
3 of data rates to determine a PER for each data rate, the SNR performance curves
4 being predetermined and stored in a memory of a receiving station.

1 25. The communication station of claim 23 wherein the data rate selection
2 circuitry calculates a bit-error rate (BER), based on a known modulation of the
3 current packet, and determines a PER for each of the plurality of data rates based
4 on a predetermined BER performance of a decoder, the calculated BER, and a
5 length of the current packet.

1 26. The communication station of claim 23 wherein the data rate selection
2 circuitry estimates a throughput for each data rate of the plurality by multiplying

3 an associated one of the data rates by one minus the PER predicted for the
4 associated data rate.

1 27. The communication station of claim 22 wherein the data rate selection
2 circuitry generates transmit power level and data rate instructions for a
3 transmitting station, the transmit power level and data rate instructions to include
4 the selected modulation and code rate and a selected transmit power level.

1 28. The communication station of claim 27 wherein the channel state
2 information processing circuitry and the data rate selection circuitry are part of a
3 receiving station, and wherein the data rate selection circuitry calculates the SNRs
4 based on a known transmit power level provided by the transmitting station in a
5 current packet, the current packet being a request to send (RTS) packet,
6 wherein the channel state information processing circuitry determines the
7 channel state information from channel estimates and noise power estimates
8 performed on the RTS packet, and
9 wherein transmitter circuitry of the receiving station sends the data rate
10 instruction to the transmitting station in a clear-to-send (CTS) packet, the
11 transmitting station to responsively transmit at least portions of a data packet to
12 the receiving station in accordance with the data rate instruction.

1 29. The communication station of claim 21 wherein the multicarrier
2 communication channel comprises either a standard-throughput channel or a high-
3 throughput communication channel, the standard-throughput channel comprising
4 one subchannel, the high-throughput channel comprising a combination of one or
5 more subchannels and one or more spatial channels associated with each
6 subchannel, and
7 wherein calculating the SNRs comprises calculating SNRs for each
8 subcarrier of the one or more subchannels and the one or more spatial channels
9 comprising the multicarrier communication channel from the transmit power level
10 and the channel state information, and
11 wherein the communication station further comprises generating a data
12 rate instruction for a transmitter, the data rate instruction to include a selected

13 modulation and a selected code rate for the one or more subchannels and the one
14 or more spatial channels comprising the multicarrier communication channel.

1 30. The communication station of claim 29 where the channel state
2 information processing circuitry further determines the channel state information,
3 the channel state information including noise power estimates and a channel
4 transfer function for each subcarrier of the one or more spatial channels and the
5 one or more subchannels.

1 31. The communication station of claim 29 wherein the high-throughput
2 communication channel comprises one of a wideband channel having up to four
3 frequency separated subchannels, a multiple-input-multiple-output (MIMO)
4 channel comprising a single subchannel having up to four spatial subchannels, and
5 a wideband-MIMO channel comprising two or more frequency separated
6 subchannels, each subchannel having two or more spatial channels.

1 32. The communication station of claim 31 wherein the wideband channel
2 has a bandwidth of up to 80 MHz and comprises up to four of the subchannels,
3 wherein the subchannels are orthogonal frequency division multiplexed
4 channels,
5 wherein each subchannel has a subchannel bandwidth of approximately
6 20 MHz and comprises a plurality of orthogonal subcarriers, and
7 wherein the one or more spatial channels are non-orthogonal channels
8 associated with one of the subchannels.

1 33. The communication station of claim 29 further comprising one or more
2 antennas to communicate over the one or more spatial channels and the one or
3 more subchannels when the multicarrier communication channel is a high-
4 throughput communication channel.

1 34. The communication station of claim 29 wherein the subcarriers of an
2 associated subchannel have a null at substantially a center frequency of the other

3 subcarriers to achieve substantial orthogonality between the subcarriers of the
4 associated subchannel.

1 35. The communication station of claim 22 wherein the plurality of
2 modulations comprise binary phase shift keying (BPSK), quadrature phase shift
3 keying (QPSK), 8PSK, 16-quadrature amplitude modulation (16-QAM), 32-
4 QAM, 64-QAM, 128-QAM, and 256-QAM, and
5 wherein the plurality of code rates comprise forward error correction
6 (FEC) code rates of $\frac{1}{2}$, $\frac{2}{3}$, and $\frac{3}{4}$.

1 36. The communication station of claim 21 wherein the data rate selection
2 circuitry further selects the data rate based on a mean-variance adaptation that
3 includes a mean channel power gain based on channel gains for each of the
4 subcarriers, a variance of the mean channel power gain, and predicted SNRs for
5 each of the data rates.
6

1 37. The communication station of claim 21 wherein the data rate selection
2 circuitry selects various data rates for each of the subcarriers of the multicarrier
3 communication channel based on the SNR for the associated subcarrier, and
4 calculates throughputs for the multicarrier communication channel for the various
5 data rates,
6 the data rate selection circuitry further selects a single data rate for the
7 subcarriers of one or more spatial channels and one or more subchannels of the
8 multicarrier communication channel.

1 38. The communication station of claim 21 wherein the data rate selection
2 circuitry calculates a subcarrier capacity for each of the data rates based on the
3 SNR calculated for an associated one of the subcarriers for each subcarrier of the
4 multicarrier communication channel,
5 the data rate selection circuitry refrains from estimating the throughput for
6 each of the data rates, and

7 the data rate selection circuitry selects one of the data rates of the plurality
8 based on a sum of the subcarrier capacities.

1 39. The communication station of claim 38 wherein the data rate selection
2 circuitry calculates the subcarrier capacity for each subcarrier substantially by
3 multiplying a subcarrier frequency spacing by a logarithm of one plus the SNR for
4 the associated subcarrier divided by a predetermined subcarrier SNR gap.

1 40. The communication station of claim 38 wherein the data rate selection
2 circuitry:
3 determines an upper and a lower data rate based on the sum of the
4 subcarrier capabilities;
5 calculates a first number of subcarriers with capacities higher than the
6 upper data rate;
7 calculates a second number of subcarriers with capacities lower than the
8 lower data rate; and
9 selects the upper data rate when a difference between the first and second
10 numbers is greater than a predetermined percentage of the subcarriers comprising
11 the multicarrier communication channel.

1 41. A system comprising:
2 a substantially omnidirectional antenna;
3 a receiver to receive signals through then antenna through a multicarrier
4 communication channel;
5 channel state information processing circuitry to calculate signal to noise
6 ratios (SNRs) for subcarriers of the multicarrier communication channel from a
7 transmit power level and channel state information; and
8 data rate selection circuitry to estimate a throughput for each of a plurality
9 of data rates from the SNRs and select one of the data rates based on the estimated
10 throughputs.

1 42. The system of claim 41 wherein the data rate selection circuitry selects
2 one of the data rates from a combination of one of a plurality of modulations and
3 one a plurality of code rates associated with a highest of the estimated
4 throughputs.

1 43. The system of claim 42 wherein the data rate selection circuitry further
2 predicts packet error ratios (PERs) from the SNRs for each of the data rates and
3 estimates the throughput comprises estimating a throughput for each of the data
4 rates from the predicted PERs.

1 44. A machine-readable medium that provides instructions, which when
2 executed by one or more processors, cause the processors to perform operations
3 comprising:
4 calculating signal to noise ratios (SNRs) for subcarriers of an orthogonal
5 frequency division multiplexed communication channel from a transmit power
6 level and channel state information;
7 estimating a throughput for each of a plurality of data rates from the SNRs;
8 and
9 selecting one of the data rates based on the estimated throughputs.

1 45. The machine-readable medium of claim 44 wherein the instructions,
2 when further executed by one or more of the processors cause the processors to
3 perform operations further comprising selecting one of the data rates based on
4 selecting a combination of one of a plurality of modulations and one a plurality of
5 code rates associated with a highest of the estimated throughputs.

1 46. The machine-readable medium of claim 45 wherein the instructions,
2 when further executed by one or more of the processors cause the processors to
3 perform operations further comprising predicting packet error ratios (PERs) from
4 the SNRs for each of the data rates, and
5 wherein estimating the throughput comprises estimating a throughput for
6 each of the data rates from the predicted PERs.